EASTERN REGION TECHNICAL ATTACHMENT
NO. 93-5A
MAY 1993

SYNOPTIC SCALE CLIMATOLOGY OF FREEZING RAIN FOR BUFFALO, NEW YORK

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1. INTRODUCTION

Freezing rain occurs when liquid precipitation falls through a layer of subfreezing air at the earth's surface. The accumulation of ice on objects such as trees, telephone poles, and utility lines can cause severe and even life threatening situations. Roadways become impassable, power and communication lines are often disrupted, and scheduled airline travel can be suspended. The cost of these damages can range well into the millions of dollars from one ice storm.

The major ice storm that occurred across western New York in March 1991 clearly illustrated the tremendous damage this type of storm can produce. Freezing rain began falling in the Buffalo area on the morning of March 3 and continued until the morning of March 4. The storm had a disastrous affect on all of western New York, including Buffalo, but the greatest impact was in the Rochester area. Freezing rain fell continuously for more than 17 hours at the Rochester Airport, with solid ice accumulations ranging from 1 to 2 inches in some places. The storm caused power outages across western New York, and at one point, almost 325,000 customers were without electricity. Nineteen counties were declared state disaster areas and 12 were declared federal disaster areas. The total storm damage exceeded $375 million, making this ice storm the costliest natural disaster in New York State history (U.S. Dept. of Commerce 1991), at that time.

This is just one example of how an ice storm affected western New York. If synoptic conditions leading to a freezing rain event could be understood and recognized with sufficient lead time, meteorologists concerned with forecasting such events would benefit. Of course, each event will have its own unique characteristics. The purpose of this study is to present a brief synoptic overview of the mean conditions associated with freezing rain events in Buffalo, NY, over the past 30 years.

2. ORGANIZATION OF DATA

Three atmospheric levels were analyzed for this study--surface, 850 mb, and 500 mb. Surface data were collected from monthly **Buffalo Local Climatological Summaries** and the **National Weather Service Daily**

Weather Map Series. The 850-mb temperature data were obtained from Buffalo radiosonde observations. The 500-mb height data and trough locations were obtained from the **National Weather Service Daily Weather Maps Series.** Freezing rain must have occurred for at least a 1-hour duration to be considered an event.

Surface data were analyzed for the entire freezing rain occurrence. The synoptic-scale surface data included the latitude and longitude of the anticyclone and cyclone center, the central pressure of the anticyclone and cyclone, and the mean surface wind direction and temperature. Cyclone type and track were also analyzed. The storm type classifications used in this study were originally developed for heavy snow events in New Jersey by Hovey and Shulman (1965). The cyclone track type is used to classify storms into seven different types, which are listed in Table 1.

The 850-mb data were from the observation time (0000 or 1200 UTC) that was closest to the beginning of the actual freezing rain occurrence. The analyzed 850-mb temperatures were evaluated.

The 500-mb data from 24 hours prior to and at the beginning of the event were analyzed. These data included: the height at Buffalo, and at the intersection of 43°N (latitude of Buffalo) with the major trough axis at the time of occurrence; the height 24 hours prior to the freezing rain occurrence over Buffalo; the angle of the trough axis with respect to longitude meridians 24 hours prior to, and at the beginning of, the freezing rain occurrence; the major trough axis longitude 24 hours prior to the freezing rain occurrence; and the major trough axis longitude at the time of freezing rain occurrence.

3. DISTRIBUTION OF EVENTS

During the period of 1962 to 1991, there were 146 freezing rain occurrences observed at Buffalo that met the criteria used for this study. However, due to the lack of data, only 117 events were analyzed. These events produced a total of 829 hours of freezing rain, or 34.54 days, with an average of 4.87 events per year. The distribution of freezing precipitation occurrences by month for Buffalo are shown in Figure 1. December and January had the greatest number of occurrences, with 37 and 32 events, respectively. February had 20 events, while March had 19. Only two events were in April, and seven events occurred in November. Based on this information, the probability of a freezing rain event by month was calculated. Since freezing rain is a relatively rare occurrence, the Poisson distribution was utilized. This equation provides the probability P(x) that 0, 1, 2,..., x unlikely events will occur independent of each other in a given period (Panofsky and Brier 1968).

The Poisson Probabilities of freezing rain by month for Buffalo are listed in Table 2. The table shows that there is a 33% chance of getting at least one freezing rain event during each winter month (December, January, February and March). There is a also a 25% chance of two freezing rain events occurring during the months of December and January. However, this is based on the assumption that each event is independent.

4. ANALYSES

4.1. Surface Data

The most frequent wind directions observed during freezing rain occurrences were from the east and the east-northeast, with 15 and 23% of the cases, respectively. Twelve percent of the events had winds from the northeast. The wind directions least observed were from the west-northwest and the south; each comprised only 2% of the data sample. Distribution of surface wind directions are illustrated in Figure 2.

Freezing rain may be possible throughout a considerable range of temperatures. The warmest surface temperature observed during an occurrence was 39°F, while the coldest observed was 12°F. The anomalously warm 39°F temperature observed in this study may have been due to a number of factors such as observer or equipment error. However, freezing rain is still possible once the surface air temperature rises above 32°F. For example, freezing rain may occur when a shallow layer of sub-freezing air is located within just a few inches of the surface, with the ground being below freezing. Temperatures recorded from a thermometer situated at a standard height of 5 ft above the ground might not detect this very shallow layer of cold air, or the cold surface temperature.

The mean surface temperature observed during a freezing rain occurrence was 29.3°F, while the mean high and low surface temperatures were 30.7 and 28.0°F, respectively. The weighted mean surface temperature was 27.7°F. The weighted mean surface temperature was calculated by multiplying the mean temperature by the length of the event and dividing the total by the total number of hours for all occurrences (Addess and Shulman 1966).

Analysis of the Daily Surface Weather Maps indicated the positions of the nearby cyclone and anticyclone. The mean anticyclone position was 48.2°N and 78.5°W, placing it approximately 480 km (290 mi) north of Buffalo along the Quebec and Ontario border. The north-south standard deviation was 6.4°, while the east-west standard deviation was 12.6°. The average central pressure was 1029.6 mb, with a standard deviation of 8.8 mb. It is important to note that 65% of the observed anticyclone centers were east of 80°W. This results in cold east to northeast winds over Buffalo common to freezing rain. If the anticyclone were located west of this position, the air flow over Buffalo would most likely be from the northwest. Air from this direction would be modified by the Great Lakes and, hence, too warm for freezing rain.

Analysis of the cyclone position and central pressure showed that there were several cyclone types and tracks that produced freezing rain in Buffalo. The mean cyclone position was 40.6°N and 85.8°W, placing the low center in central Indiana at the onset of freezing rain. The north-south standard deviation was 4.9°, while the east-west standard deviation was 10.0°. Figure 3 shows the mean cyclone and anticyclone positions at the time of freezing rain. The average cyclone central pressure was 1000.2 mb, with a standard deviation of 11.9 mb.

The most predominant storm type leading to freezing rain was Type 1. This category produced 39 total occurrences, comprising 33% of the total sample and occurred during every month in which there was an event.

Most of the freezing rain associated with these systems was due primarily to warm air advection aloft overrunning cold air at the surface. The least common cyclone was Type 5, which had 3 occurrences and comprised only 3% percent of the sample. Table 3 summarizes cyclone type by month.

4.2. 850-mb Data

At 850 mb, the mean temperature for all the cases studied was -0.85°C, while the weighted mean was the same. This does not appear to fit the classic theory for the occurrence of freezing rain (i.e., a warm layer with above freezing temperatures existing above a cold shallow layer at the surface). One factor that may have contributed to the below freezing 850-mb mean temperature may be the times at which the upper air data are obtained. Freezing rain in most of the cases occurred at times other than when the upper air data were collected. In this study, the 850-mb temperature was obtained from the sounding that was closer to the time of the freezing rain occurrence. The actual temperatures aloft at these times might have differed substantially from those indicated by previous soundings.

4.3. 500-mb Data

The analysis of the 500-mb level data revealed the following results. Thirty one percent of the cases studied involved closed lows at 500 mb. Of the systems that were open waves, the 500-mb trough axis was generally orientated in a north-south direction with a slight positive tilt, both 24 hours prior to and at the time of freezing rain occurrence.

Knowledge of the position of the 500-mb major trough axis during and 24 hours prior to a freezing rain occurrence is necessary for the identification and prediction of these events. The mean 500-mb trough axis position was 106.5°W 24 hours prior to the onset of freezing rain. Twenty-four hours later, the trough axis showed a mean movement of 12.2°, or 950 km, to the east. This placed the mean axis at 94.3°W for the onset of freezing precipitation. Figure 3 shows these positions.

The 24-hour 500-mb height difference between Buffalo and the intersection of 43°N with the major trough axis is an indication of the amplitude of the trough. The mean 500-mb height over Buffalo at the beginning of freezing rain was 576 dm, while the mean height at the trough axis was 540.7 dm. Hence, the mean height difference was 35.3 dm between the two locations. Twenty-four hours prior to the freezing rain events, the mean height over Buffalo was 553.5 dm, which resulted in a mean 24-hour height rise of 22.7 dm. This is of importance because it reveals an apparent increase in trough amplitude 24 hours prior to and at the beginning of freezing rain events. Addess and Shulman (1966) found similar results in their analysis of freezing rain for New Jersey. Additionally, this height rise implies that ridging takes place over Buffalo during the 24 hours prior to the occurrence of freezing rain.

5. SUMMARY AND CONCLUSION

Freezing rain is one of winter's most frightening and destructive phenomena. The results of this study indicated that there is a 33% probability of a freezing rain event occurring in Buffalo during the winter months of December through March. This analysis was carried out to determine the mean conditions leading up to and producing freezing rain. It is intended to aid the operational meteorologist concerned with forecasting these events in real time.

Synoptic analysis of freezing rain events at the lower levels indicated that the 850-mb mean temperature during freezing rain was -0.85°C, and the mean anticyclone position at the surface was approximately 480 km (290 mi) north of Buffalo, with an average central pressure of 1029.6 mb. The most common cyclone type leading to the occurrence of freezing rain usually developed in the Southern Plains and moved to the Ohio Valley. These storms then filled, with the development of a secondary system along the East Coast. At the time that freezing rain began, the mean surface cyclone was positioned in central Indiana with an average central pressure of 1000.2 mb.

Analysis of the 500-mb level showed that the 500-mb trough axis was generally orientated in a north-south direction with a slight positive tilt, and the mean 500-mb trough axis 24 hours prior to freezing rain was located over eastern Montana and Wyoming. At the onset of freezing rain, the trough axis had moved to near central Iowa and western Missouri. A mean 24-hour 500-mb height rise of 22.7 dm was found to occur over Buffalo, indicating substantial ridging. Thirty-one percent of the cases studied were associated with closed lows.

The large-scale synoptic patterns mentioned in this study can be easily recognized and are common to freezing rain events in western New York. With operational numerical models providing accurate predictions of 24-hour 500-mb trough movement and height changes, meteorologists who forecast in this region should be able to recognize these patterns. Additionally, upper air data can be obtained at forecast offices on a day-to-day basis and should be used to determine the elevation of warm layers associated with freezing rain events. In the very near future, high resolution gridded model data and prognostic model soundings will also assist with the determination of the atmospheric thermal structure.

References

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Table 1. Cyclone track and type, following Hovey and Shulman (1965).

Type 1. Storms that develop in the Southern Plains, usually over the Texas or Oklahoma Panhandles, and then move to the Ohio Valley and fill with secondary development along the East Coast.

Type 2. Similar to type 1, except that the primary storm system moves out to sea. There is no secondary development.

Type 3. Development in the Gulf of Mexico with movement up the East Coast.

Type 4. Development in the Gulf of Mexico with north movement west of the Appalachians and secondary development along the East Coast.

Type 5. Development in the mid-Mississippi Valley or Tennessee with or without secondary development along the coast.

Type 6. Low pressure systems which drop southeast out of the Northern Plains or Great Lakes region and then move out to sea.

Type 7. Any cases that could not be placed in Types 1 to 6.

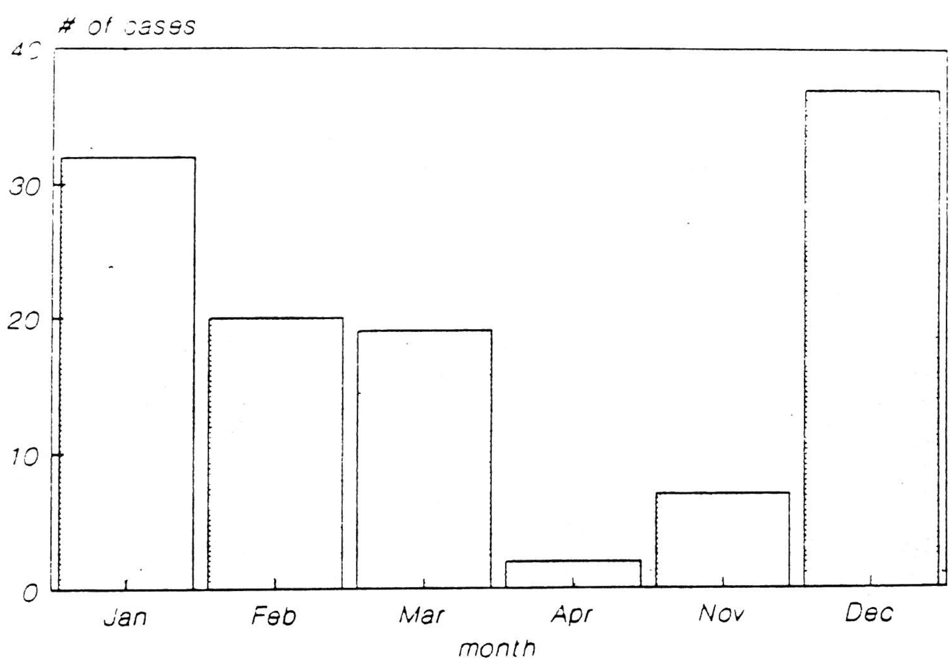

Figure 1. Frequency distribution of freezing rain occurrence by month for Buffalo, NY.

Table 2. Probabilities of occurrence of freezing rain by month based on the Poisson Distribution.

	Number of Occurrences				
	1	2	3	4	5
Month					
January	.345	.241	.112	.039	.011
February	.364	.158	.046	.010	.002
March	.359	.144	.038	.008	.001
April	.029	.000	.000	.000	.000
November	.182	.021	.002	.000	.000
December	.330	.253	.129	.049	.015

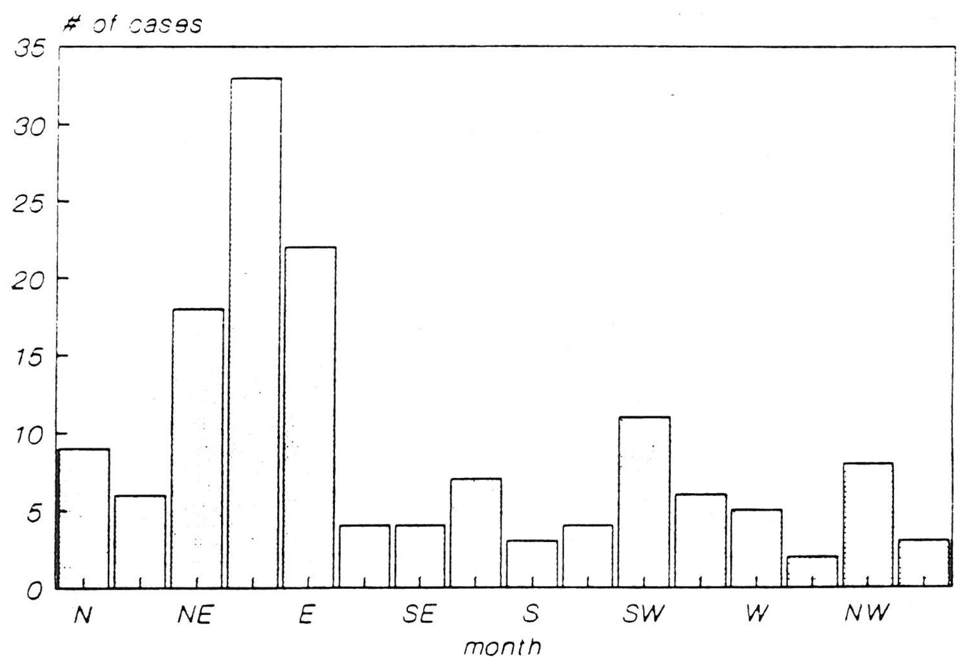

Figure 2. Frequency distribution of wind direction during freezing rain at Buffalo, NY.

Table 3. Frequency of freezing rain storms by type, following Hovey and Shulman(1965).

Type	January	February	March	April	November	December	Total
1	11	6	8	1	3	10	39
2	0	3	1	0	2	4	10
3	9	1	3	0	1	4	18
4	5	5	1	0	0	3	14
5	0	0	0	0	1	2	3
6	2	2	2	1	0	2	9
7	5	3	4	0	0	12	24

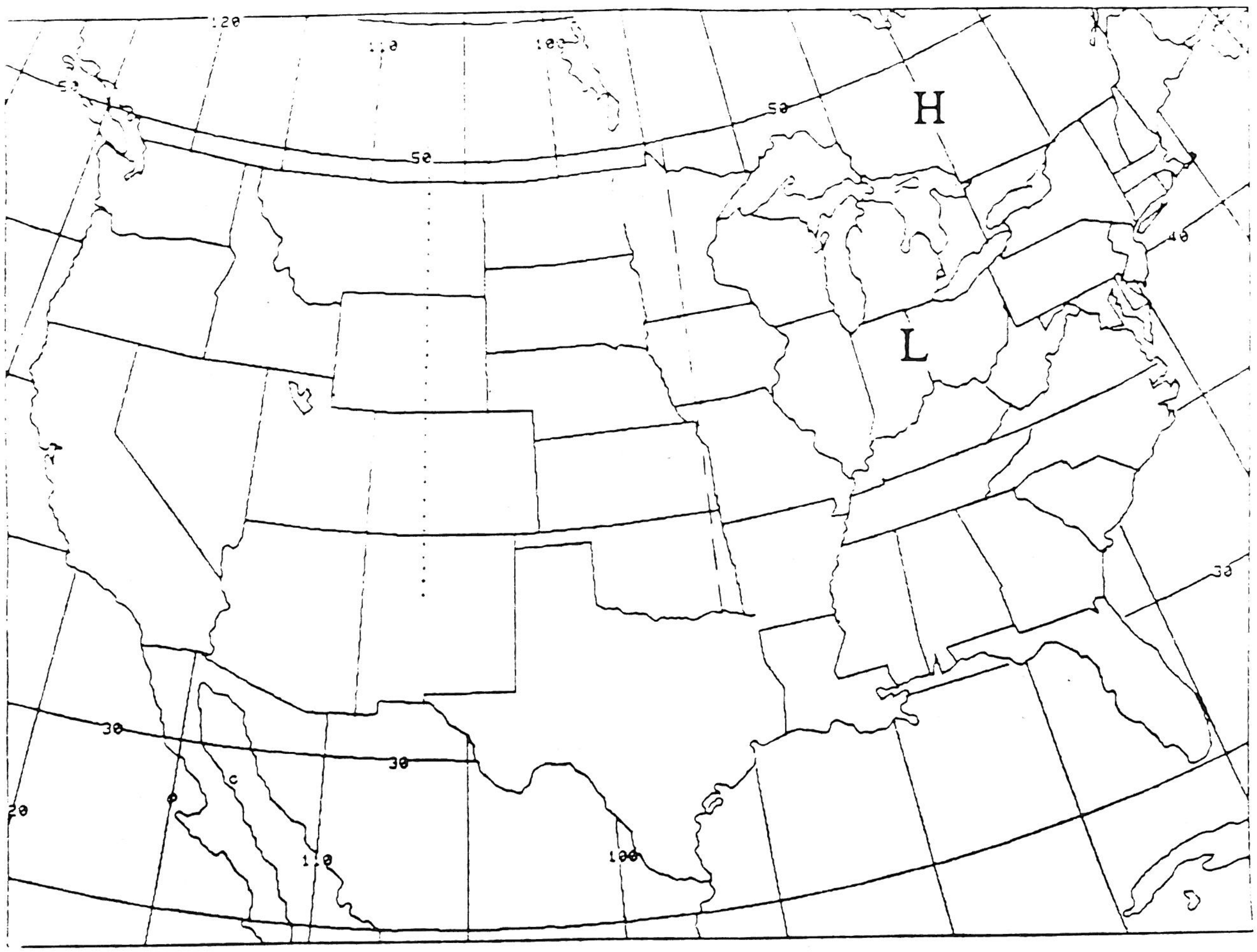

Figure 3. Mean surface cyclone (L) and anticyclone (H) positions at the time of freezing rain. Mean 500-mb trough axis position 24 hours prior to (dotted line) and at the onset of (dashed line) freezing rain.